ASPECTS REGARDING FUNCTIONAL STABILITY OF DEMOUNTABLE JOINTS USED IN SOLID WOOD CHAIRS

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RESEARCH ARTICLE

Abstract

The objective of the present study was to optimise and streamline the assembly process of solid wood chairs by applying more efficient ironmongerys to demountable joints

Industrial tests were realized and implemented on solid wood chairs and took place at a company in Sighetul Marmaţiei.

The test results showed the advantages of the application of these ironmongerys, namely: reduction of assembly time, reduction of the number of machining operations per parts, high resistance to the stresses to which they are subjected.

Based on tests, it was found that such ironmongery can be successfully implemented in the wood industry when assembling solid wood chairs or various wooden structures.

This substantially reduces the assembly time and the machining time of the parts, resulting in increased production.

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INTRODUCTION

The chair is made of solid wood.

The component parts are machined from hardwood lumber by cutting, and the frame assembly is based on mortise and tenon jointed, either with applied straight or round tenon

Mortise and tenon jointed is simple and very strong and is mainly used for joining elements at 90º.

This is a tenon made at the end of a piece of wood that fits perfectly with a mortise in another piece of wood.

There are several variations of the joint, each of them having an added strength or esthetics or resolves some more complicated problems.

The assembly between the two elements must be made a little forced, without play, but without forcing too much.

A joint where the tenon enters very difficult risked to give in at the slightest expansion of the wood.

(https://woodenmagazine.ro/2019/01/10/mortise-and-tenon-the-most-used-traditional-joint-for-furniture/)

The benefits of lag screw joints include less loosening and slippage when a load is first applied than bolted timber joints; however, they also require more caution, making construction management an important consideration [Inoue-Shoin Co. Ltd., 2012.].

For example, screwing in a lag screw without first drilling a pilot hole can cause the timber member to crack, or driven in using a hammer. In addition, overtightening beyond a lag screw's pullout strength risks damaging the joint, weakening it compared with its original performance.

One potential solution to prevent the latter scenario is to apply a torque control method to provide suitable torque by means of a torque wrench or other tool. (Matsubara D.at al. 2018)

MATERIAL AND METHOD

Joints of elements, panels, sub-assemblies and their assemblies are used to produce various mechanical structures in the construction of different types of furniture as well as finished wooden products.

The solid wood chairs under test are made at a company in Sighetul Marmaţiei.

In the case of round-tenon joints made by clamping, a circumferential pressure pf arises between them and the joined parts in the radial direction, the expression of which is [Curtu I et al. 1981]:

$$p_f = \frac{\delta}{c\left(s_{11}^{(1)} + s_{12}^{(2)}\right) + \frac{(bc)^{1+e^2}}{b^{2e_2} - c^{2e_2}} \cdot \frac{c^{e_2}}{b^{2+e_2}} \left[\left(s_{11}^{(2)} + s_{12}^{(2)}\right) - \frac{b^{e_2-1}}{c^{e_2}} \left(s_{12}^{(2)} - s_{11}^{(2)}\right) \right]} \quad (1.1)$$

or by entering the notation $b = \alpha c$ it is obtained

$$p_f = \frac{\delta}{c\left\{ s_{11}^{(1)} + s_{12}^{(1)} + \frac{\alpha^{1+e_2}}{\alpha^{2e_2-1}} \left[\frac{s_{11}^{(1)} + s_{12}^{(2)}}{\alpha^{1+e_2}} - \frac{s_{12}^{(2)} - s_{11}^{(2)}}{\alpha^{1-e_2}} \right] \right\}} \quad (1.2)$$

where the meaning of the terms is as follows

- for tenon

$$s_{11}^{(1)} = \frac{1}{E_T^{(1)}}; s_{12}^{(1)} = -\frac{\nu_{TR}^{(1)}}{E_R^{(1)}}$$

- for mortise

$$s_{11}^{(2)} = \frac{1}{E_T^{(2)}}; s_{12}^{(2)} = -\frac{\nu_{TR}^{(2)}}{E_R^{(2)}}; s_{22}^{(2)} = \frac{1}{E_R^{(2)}}; e_2 = \sqrt{\frac{s_{22}^{(2)}}{s_{11}^{(2)}}} = \sqrt{\frac{E_T^{(2)}}{E_R^{(2)}}}$$

$k_{1,2} = -1 + e^2; \alpha = 1{,}5; 2{,}0; 2{,}5; 2\delta$ = tightening

Note that in relation (1.1)determined pressure has not been taken into account and swelling of the tenon due to moisture variation in the adhesive film, as well as elastic relaxation.

By following the deformation mode of the round tenon joints (fig. 1 *a*) and with eccentric (fig. 1 *b*) determined with the method *moiré-urilor*, areas of maximum deformation can be observed (tensile or compression). From Fig. 1 a and b it can be observed that joints with tenons are less rigid than those with bolts or eccentrics.

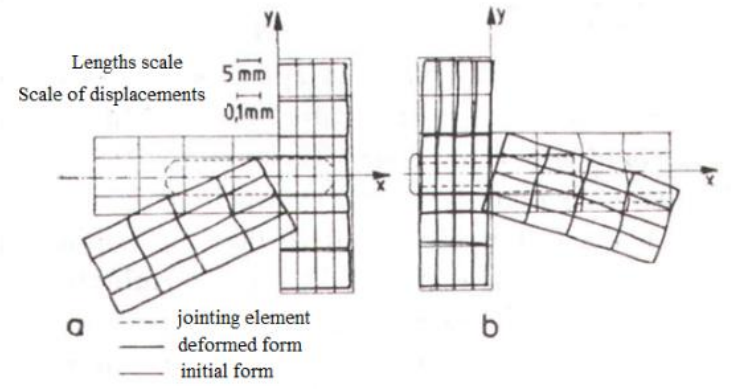

Figure 1 **Deformation mode of round tenon and eccentric joints [Curtu I et al. 1981]**

For 90° joints with round tenon (fig. 2) tensions are generated by shear forces $T = Q$ and bents moments $M_t = Ql_0$. In the case of strength calculation the following assumptions are allowed: the tenon is made of a stronger material than the material of the joining pieces; the strength of the glue is at least equal to that of wood; between the pieces there are no games.

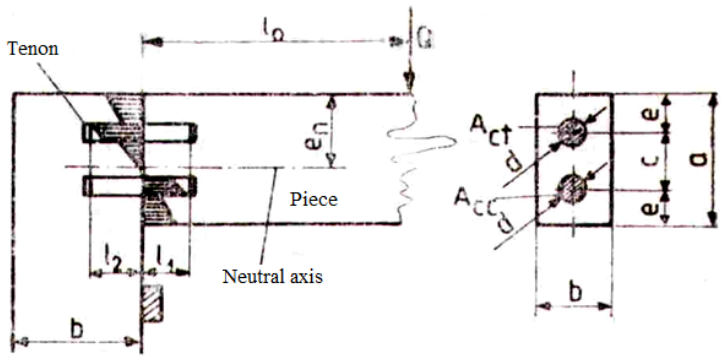

Figure 2 **90° joints with rounded tenons [Curtu I et al. 1981]**

RESULTS AND DISCUSSIONS

On the basis of the tests performed when assembling the chairs by mortise and tenon jointed, a jointed well-known, a considerable difference was observed between their bolt assembly which requires more processing of the part and eccentric assembly which is more accessible, easier to mount.

Figure 3 **a) Bolt assembly crosspiece**

b) Eccentric assembly crosspiece

In the image below it can be seen glued parts between mortise and tenon. To join the parts on the crosspiece channel, insert the bolt.

Mortise and tenon it is joined with glue or wood glue, but the excess glue will go into that bolt channel. To the technological process in the gluing phase is necessary the intervention of a worker to ensure the cleaning of the hole for the bolt after the gluing operation.

Figure 4 **The crosspiece channel**

In case of eccentric assembly highlighted in the images below, some processing on parts is no longer necessary. It can be noted those two tenons of 10 mm x 20 mm long without mortise and without bolt channel. Through tenons in the middle of the crosspiece, it can be mounted in any position, thus choosing the most aesthetically favorable way.


Figure 5 **Eccentric assembly withouth mortises and withouth bolt channel**

Versus bolt assembly, eccentric assembly has the advantage of eliminating some processing on the part that is more difficult to realize and offers the possibility to choose how to mount the assembly

In the bolt assembly where the crosspiece with mortise is used, on the crosspiece 3 holes of 30 mm are processed next to each other while are processed to eccentric assembly just a hole where the eccentric is inserted. This eliminates the processing of the three holes on automatic machines thus reducing assembly processing time and increasing the production of chairs.

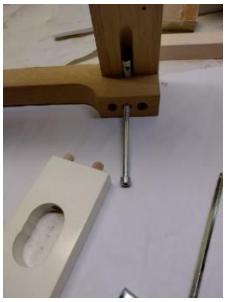


Figure 6 **a) Crosspiece with 3 holes to bolt assembly** **b) Crosspiece with 1 hole to eccentric assembly**


Figure 7 **a) Fixing the bolt** **b) Eccentric assembly whitout bolt**

Bolt assembly it is mounted using a screwdriver to fix the bolt. In the case of eccentric assembly, the mounting of the bolt is eliminated

The disadvantage in the case of bolt assembly is the threading of the screw which requires a certain number of threads as well as the insertion of the crescent in the 3 holes.

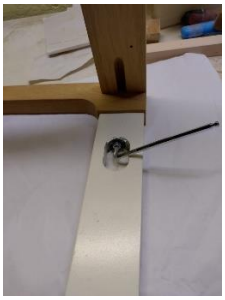

Figure 8 **a) threading of the screw** **b) threading of the eccentric**

With bolt assembly the threading time is longer than with eccentric assembly, threading time is reduced using eccentric assembly

Figure 9 **a) End of bolt assembly** **b) End of eccentric assembly**

CONCLUSIONS

After the tests it was concluded that:

- Eccentric assembly helps in processing the pieces by eliminating some processed on the parts
- There is no glue left in the holes after the parts are assembled
- A hole is easier to make than a mortise
- Versus bolt assembly, eccentric assembly has the advantage of eliminating some processing on the part that is more difficult to realize and offers the possibility to choose how to mount the assembly
- Due to less processing, production costs decrease
- Increase production
- Eccentric assembly compared to conventional structures have a higher resistance to all types of stresses to which they are generally subjected.
- Practically, such a structure becomes indestructible regardless of the type of request to which the structure is subjected.

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